Tracking Change Over Time—River Flooding

Time Estimate: 1–2 class periods

Suggested grade levels: 5–8

Materials needed: projection system (computer with projector or SMART Board); Internet access

Vocabulary: flood stage, oxbow lake, cutoff, meander, meander scar, Pythagorean theorem, hypotenuse

National Science Education Standards (NSES)

- Science in Personal and Social Perspective:
  - Populations, resources, and environments.
  - Natural hazards.

American Association for the Advancement of Science (AAAS) Benchmarks

- The Mathematical World/Shapes
  - Relationships exist among the angles between the sides of triangle and the lengths of those sides. For example, when two sides of a triangle are perpendicular, the sum of the squares of the lengths of those sides is equal to the square of the third side of the triangle. (9C/M9)
- The Physical Setting/The Earth
  - Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the oceans. The cycling of water in and out of the atmosphere is a significant aspect of the weather patterns on Earth. (4B/M7)

National Geographic Education Standards

- Standard 1: How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.
- Standard 15: How physical systems affect human systems.

National Council of Teachers of Mathematics Standards

- Geometry
  - Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.
    - create and critique inductive and deductive arguments concerning geometric ideas and relationships, such as congruence, similarity, and the Pythagorean relationship.
  - Use visualization, spatial reasoning, and geometric modeling to solve problems.
    - recognize and apply geometric ideas and relationships in areas outside the mathematics classroom, such as art, science, and everyday life.
- Measurement
  - Understand measurable attributes of objects and the units, systems, and processes of measurement.
    - understand both metric and customary systems of measurement.
    - understand relationships among units and convert from one unit to another within the same system.
  - Apply appropriate techniques, tools, and formulas to determine measurements.
    - develop and use formulas to determine the circumference of circles and the area of triangles, parallelograms, trapezoids, and circles and develop strategies to find the area of more-complex shapes.

Overview

In this module, background information and study questions for analysis and interpretation lead students to discover how a flood in June 2008 affected an area of southern Indiana and Illinois. The module takes a problem-based approach to show students how satellite images can be used to analyze the changes that a flood causes.

In the “Analysis and Interpretation” section, you will find several essential questions. As time permits, the “Extended Learning” section can be used. Of course, you may choose the questions you feel are most appropriate for your class. You could assign individual students to answer specific questions, or divide the questions among the class. Students could also work in pairs or teams.

Learning Goals

Students will

- Use study questions to analyze the changes a specific flood caused.
- Explore the damage and change that a flood can cause using Landsat images and the MultiSpec software.

Background

These three Landsat 5 images show a flood in southern Indiana and Illinois. Peak flooding was observed in this area on June 10 and 11, 2008. The clear Landsat scene from June 11, 2008, and the clear image of “normal” conditions from June 9, 2007, allow us to compare the scenes and see exactly what damage a flood of this magnitude can cause.

Rainfall amounts ranging from about 2 inches (in.) to more than 10 in. fell in this area on June 6–7, 2008. Because of a wetter than normal spring, this heavy rain fell on already saturated ground. The rivers quickly rose to exceed flood stage.

U.S. Department of the Interior
U.S. Geological Survey
General Information Product 133a

The following files are the images to use in MultiSpec:

- Flood_June2007.tif
- Flood_June2008.tif
- Flood_July2008.tif

June 9, 2007—Landsat 5

June 11, 2008—Landsat 5

July 13, 2008—Landsat 5

Analysis and Interpretation

Essential Questions

1. What band combination best shows rivers? Band combinations 7,4,3 and 5,4,3 show water and the extent of flooding very clearly.

2. Identify an area of farmland that is inundated. The area around latitude/longitude (lat/long) 38.99, –87.04 is normally farmland. In the June 2007 image, polygons that are red (4,3,2) or green (5,4,3) indicate cropland. In the June 2008 image, these fields are underwater, shown by turquoise (4,3,2) or blue (5,4,3). Students might identify other inundated farms. Remind students how to find lat/long coordinates from “Using MultiSpec to Interpret Satellite Imagery,” section 3, step 4.

3. Find a flooded area that covers at least an entire section (640 acres). (See “Using MultiSpec to Interpret Satellite Imagery,” step 7, for instructions on how to calculate area.) The area around lat/long 39.32, –87.23 covers more than a section; another example is lat/long 39.05, –87.00. See if students find others.

4. Identify at least one city/town that was affected by this flood. Recall the list of common band combinations from the “Using MultiSpec to Interpret Satellite Imagery” section. You may also need to use Google Maps or Google Earth to identify cities. Several communities were near a flooded river, but it’s worth locating Worthington, Ind., at lat/long 39.11,–86.98, which is surrounded by the floodwaters of the White and Eel Rivers.

5. In the 2008 flood image, what could account for the large, nearly square-shaped area of floodwater at lat/long 39.31, –87.23? How many acres does it encompass? About 2,200 acres. The fact that this area became inundated indicates that it is low lying land. It’s possible that during the flood, water flowed from the nearby Eel River through a breach. The 2007 image shows this area as cropland, which is commonly low and flat. Roads, built up above ground level, could be causing the straight lines that appear. Interestingly, this spot was once an artificial reservoir, called the Splunge Creek Reservoir, that formed to supply water to the Wabash-Erie Canal, which no longer exists.

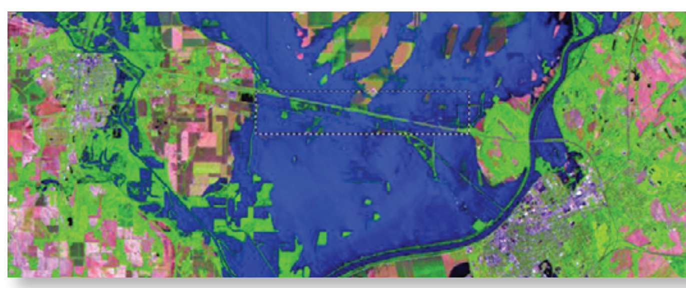
6. In the 2008 flood image, at about lat/long 39.31, –87.58, there seem to be rectangular islands in the middle of the water. What could be causing these areas to appear unflooded? These could be forested areas or stands of trees, so even though the land surface is flooded, the trees are visible above the water level.

7. In the 2007 image, a large area at about lat/long 38.76, –87.59, band combination 5,4,3, contains some green fields, but some fields are maroon and others pink. Why are these fields different colors? In this band combination, bright green is healthy vegetation, so the crops are growing well in those fields. Some fields have a faint green color; crops are growing in those fields, but they are younger than the crops in the bright green fields. The pink and maroon fields are bare soil, probably planted but there is no growth yet. The bright pink fields have slightly less moisture in the soil.

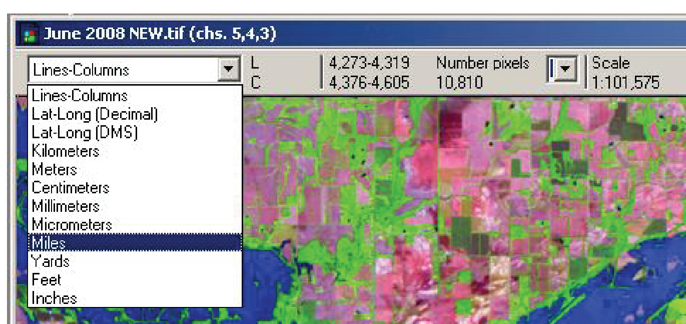
MultiSpec Application: Using the Pythagorean Theorem to Calculate Distance

In the June 2008 flood image, locate the cities of Vincennes, Ind. (lat/long 38.68, –87.52), and Lawrenceville, Ill. (lat/long 38.72, –87.60). A straight highway (Highway 50) connects the two cities and seems to be traversing a large flooded area. Use MultiSpec to find out how many miles of flooded area this highway passes through.

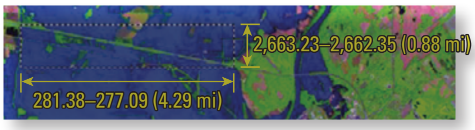
1. With the mouse, select a rectangle so that either end of the highway is in the opposite corner of the rectangle.



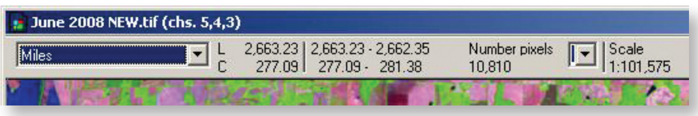
2. Under the Window menu, select Show Coordinate View. Change the units to miles.



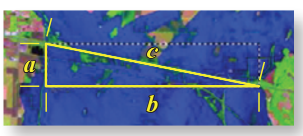
3. Notice how the range of numbers is now shown as a range of miles. These numbers represent the dimensions of the rectangle you drew on the MultiSpec image in miles.
   - The length of the short side of the rectangle is 2,663.23–2,662.35 (0.88 miles).
   - The length of the long side of the rectangle is 281.38–277.09 (4.29 miles).



   - The exact dimensions of your rectangle might be a little bit different from the given numbers here. That's okay. We should come up with almost the same answer.



4. You can now calculate the distance from one corner of the rectangle to the other using the Pythagorean theorem ($a^2+b^2=c^2$). The answer will be the length of that stretch of highway. Notice that the rectangle can be seen as two right triangles on top of each other.



   - c is the length of the hypotenuse of the right triangle (the diagonal line), and a and b are the lengths of the other two sides.

5. Insert the numbers you know into the formula:

$$0.88^2+4.29^2=c^2$$
$$0.7744+18.4041=c^2$$
$$19.1785=c^2$$

6. Now we need the square root (√) of that number to solve for c:

The square root of 19.1785 is about 4.38. $\sqrt{19.1785} = 4.38$

7. The length of highway that crosses this flooded area is about 4.38 miles. Let's make sure this answer makes sense. The length of the diagonal line in the rectangle should be a little bit longer than the longest side of the rectangle. 4.38 is a little longer than 4.29, so our answer makes sense.

See if there is another place where students can use this method to calculate the length of a line that is not horizontal or vertical. Maybe to determine the distance between two cities, or the distance across a flooded part of a river.

Extended Learning

Floods are examples of short-term environmental change. They cause substantial damage and change for only a short time, such as a couple of weeks. The damage done to crops can last for an entire growing season, but in most cases, the landscape goes back to normal after the floodwaters recede. In some cases, however, a flood can cause more lasting change.

Downstream from the area that we studied for this module, the flood changed the course of the Wabash River just above where it flows into the Ohio River. We have to go to a different Landsat image to see this happen, the one just south of the scene we've been examining. Images show a new cutoff that was formed from this flooding (provided on the disk and at *http://eros.usgs.gov/educational-activities*). Open the following images:

- Cutoff_6-9-2007.tif
- Cutoff_6-11-2008.tif
- Cutoff_7-13-2008.tif
- Cutoff_6-30-2009.tif
- Cutoff_8-4-2010.tif
- Cutoff_6-4-2011.tif
- Cutoff_6-14-2012.tif
- Cutoff_8-28-2013.tif

Images can be opened as regular .jpgs or you can open them in MultiSpec. Both types of files are provided.

Cutoffs are common on meandering rivers like the Wabash, but it's rare to be able to witness a cutoff forming as it happens. Scientists used this cutoff as a chance to learn more about what happens when these cutoffs develop and how cutoffs change after they form.

- Use the August 28, 2013, image to estimate the area of the land that is now inaccessible. See "Using MultiSpec to Interpret Satellite Imagery," step 7. A reasonable estimate would be about 2,200 acres.
- Estimate how much this new cutoff shortens the Wabash River. Students can use the same technique as in the MultiSpec application. For this calculation, however, they will have to use a series of rectangles along the curving path of the river and add the calculations together to get an estimate of the length of this section of river. The more rectangles they use, the more accurate the estimate will be. From the point where the new cutoff begins to where it ends is about 1,380 meters (m), or 0.86 miles. The original length before the cutoff is about 13,711 m, or 8.5 miles. Therefore, an answer of about 7.5 miles is a decent estimate of how much the river was shortened by this cutoff. Note that you can have students convert units anywhere in the process to demonstrate that there is more than one way to solve a problem. Another assignment could be to have students, or teams, write a paper to describe exactly how they arrived at their estimate.
- In the 7,4,1 band combination, the color pink indicates bare soil, which includes farmland that is either not planted or planted but the crops have not grown yet, or sediment in a river. Why does sediment appear in some parts of the river and not in others? A meander is a bend in a river. A river can form a meandering course (meaning that it snakes back and forth) by eroding sediments from the outside of the bend where the water moves fast, and depositing the sediments on the inside of the bend where water moves slower. Where the water slows down, the river drops sediment, so sediment is typically seen along the inside of these bends. There are also other spots where sediment has been deposited—see if students can explain a theory for why the river slows down in these other locations indicated by the presence of sediment.

- Change the band combination to 3,2,1. How does river sediment appear? The river sediment appears bright white. This makes 3,2,1 even more useful for tracking river sediment.
- What issues arise concerning the farmers who own this land that is now surrounded by the river? Once the cutoff formed, farmers were unable to access their land.
- What should be done with this land now?

More about This Flood

The flooding that happened in summer 2008 in Indiana and Illinois started late in 2007 with above normal snowfall. This extra snow saturated the ground in the spring. The above normal rainfall in the spring only made the situation worse. (Many U.S. Geological Survey streamgages in the region already showed stream levels at higher than average streamflow.) The heavy rainfall event on June 6–7, while by itself might not have caused catastrophic flooding, combined with the saturated conditions from the previous winter snows to cause this flood.

On June 6, 2008, a nearly stationary weather front was draped across south-central Indiana, and moisture from the Gulf of Mexico streamed north to fuel thunderstorm development. Nearly continuous thunderstorms over 12–16 hours dumped several inches of rain on the region. This rain flowed into the already high rivers and streams, which rose quickly.

Satellite images can help authorities on the ground respond to disasters such as floods. The images can help local authorities see the amount of flooding and where there is damage to property. The extent of the flood can be mapped so that response teams can view where they are needed and respond quickly.

Be sure to view the three animations provided on the disk and at *http://eros.usgs.gov/educational-activities*. These animations show close-ups of three different areas and can help students visualize the rapid change caused by this flood.

Lesson Extension: Scavenger Hunt

Using any of the three entire images, send students on a scavenger hunt to find the following features or structures: (answers for the teacher provided in lat/long)

Using any of the three entire images, see if you can find the following features or structures. Provide the latitude/longitude coordinates of the locations.

- **Oxbow lake:** a U-shaped lake next to a river, formed when a curve, or meander, in a river gets cut off from the river's main flow. One oxbow lake is at lat/long 38.90, –87.12.
- **Meander scars:** the shape of an old oxbow lake after it has dried up or has been filled in with sediment and soil; several meander scars can be seen from space next to meandering rivers. There are some meander scars in the vicinity of lat/long 38.90, –87.14.
- **Forested area:** Large forested areas are on the eastern side of the image, evidenced by bright green in the 5,4,3 band combination or bright red in the 4,3,2 band combination. Forest, in these images, can be distinguished from agriculture because forests typically do not have the distinctive rectangular patterns that farm fields do.
- **Center-pivot irrigation field:** In the 2007 image, there are a few near lat/long 38.77, –87.60.
- **Highway:** Highways are clear in the 5,4,3 band combination as long, mostly straight dark lines.
- **Highway interchange:** A noticeable highway interchange is at lat/long 38.68, –87.488, near Vincennes, Ind.
- **Reservoir (artificial lake):** East Fork Lake, near Olney, Ill., is located at lat/long 38.76, –88.06. There are many others.
- **Widest spot on a river during the flood:** Probably at lat/long 38.71, –87.57; to be fair, however, this spot is where two rivers come together. The widest spot with a single river is likely at lat/long 38.84, –87.19. If students have different answers, ask them to explain how they arrived at their answer.

Resources

Ahlberg, L., 2011, Researchers' chance viewing of river cutoff forming provides rare insight: News Bureau, University of Illinois, September 21, 2011. (Also available at *http://news.illinois.edu/news/11/0921riversediment_BruceRhoads.html*.)

Atlas of Science Literacy, American Association for the Advancement of Science (AAAS), Project 2061, Washington, D.C., 2001, 2007.

Cox, E.T., 1869, First Annual Report of the Geological Survey of Indiana, accessed June 12, 2012, at *http://www.indiana.edu/~libgeol/cox1869/69cox.html*.

Hay, J., 2010, Wabash River cuts a new channel, accessed October 26, 2011, at *http://www.riverlorian.com/wabashrivercutoff.htm*.

Holmes, R.R., Jr., Koenig, T.A., and Karstensen, K.A., 2010, Flooding in the United States Midwest, 2008: U.S. Geological Survey Professional Paper 1775, 64 p. (Also available at *http://pubs.usgs.gov/pp/1775/*.)

Hussain, E., Kim, K., and Shan, J., 2009, Object-based image classification and web-mapping techniques for flood damage assessment, Annual Conference, Baltimore, Md., 9–13 March 2009, Proceedings: Bethesda, Md., American Society for Photogrammetry and Remote Sensing, unpaged CD-ROM.

Morlock, S.E., Menke, C.D., Arvin, D.V., and Kim, M.H., 2008, Flood of June 7–9, 2008, in central and southern Indiana: U.S. Geological Survey Open-File Report 2008–1322, 15 p., 3 app. (Also available at *http://pubs.usgs.gov/of/2008/1322/*).

The National Academies Press, 1996, National Science Education Standards (NSES): Washington, D.C., National Academy Press. Available online at *http://www.nap.edu/openbook.php?record_id=4962*.

National Geographic, 2008, National Geographic Xpeditions—Geography Standards: U.S. National Geography Standards, accessed August 30, 2012, at *http://www.nationalgeographic.com/xpeditions/standards/matrix.html*.

National Council of Teachers of Mathematics, Principles and Standards for School Mathematics: Math Standards and Expectations, accessed August 30, 2012, at *http://standards.nctm.org/*.

MathIsFun.com, 2011, Pythagoras' Theorem: MathIsFun Web site, accessed October 26, 2011, at *http://www.mathsisfun.com/pythagoras.html*.

Service Assessment Team, 2009, Service Assessment—Central United States Flooding of June 2008: Silver Spring, Md., National Oceanic and Atmospheric Administration, National Weather Service.

Shaw, R.E., 1990, Canals for a Nation—The Canal Era in the United States, 1790–1860: Lexington, University Press of Kentucky, 304 p.

Wilkinson, P., and Stoelting, N., 2008, Lower Eel River Watershed Management Plan: Clay County Soil & Water Conservation District, 109 p., accessed June 12, 2012, at *http://www.in.gov/idem/nps/files/wmp_eelriver-lower_5-134.pdf*.

Wilson, M., 2008, Floods shift Wabash River—new path at Mackey Bend: Evansville Courier & Press, July 13, 2008, accessed October 26, 2011, at *http://www.courierpress.com/news/2008/jul/13/floods-shift-wabash/*.

Zinger, J.A., Rhoads, B.L., and Best, J.L., 2011, Extreme sediment pulses generated by bend cutoffs along a large meandering river: Nature Geoscience, v. 4, p. 675–678. (Also available at *http://www.nature.com/ngeo/journal/v4/n10/full/ngeo1260.html*.)

http://dx.doi.org/10.3133/gip133A